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Application of Remote Sensing and Geographic Information System for settlement land use classification planning in Bantul based on Earthquake Disaster Mitigation (Case Study: Bantul earthquake, May 27th 2006)

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Abstract

An earthquake occured in Daerah Istimewa Yogyakarta and Central Java on May, 27th 2006 was one the biggest earthquake in Indonesia. The earthquake was about 5.9 Richter scale and made many victims. The previous research showed that the most damaged area was around the Opak Sesar in Bantul. This fact actually indicates that the Opak Sesar had the influence for the damage on that earthquake. Bantul District is a region which has variation of landuse such as settlement, agriculture area, tourism, and conservation area. Unfortunately, the distribution of this landuse still not considers on the disaster management aspects.

This paper is purposed to clasify and mapping the Bantul area in two main classes, settlement and non settlement area based on earthquake management consideration and using the remote sensing and geography information system method. The settlement is the most essensial part which include the human so it should be saved more than other area. The mapping considered some parameters, which every parameters has to be scored to clasify the area. The mapping process used Landsat 7 ETM+ image of Bantul area, recorded in 2007 and secondary data from the previous research in 2006. This research can be also to evaluate the existing 'Regional Planning' from Bantul goverment. The results of this paper actually not to change the real landuse condition directly, but it can be a suggestion area design for the goverment to manage the area planning at the future.

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Keywords: Bantul Earthquake; Settlement; Remote Sensing; GIS; Map Design

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1. Introduction

As the population growth, the demand for housing is also increasing. Human will be always doing adaptation to their environmental conditions, including for building the house, forming a community, and working. However, sometimes the threat and danger of disaster are being forgotten. The combination of remote sensing and GIS methods can be applied to many things, including the suitability assessment of land use. There are various conditions or characters that can be used as a reference to be used as a land settlement. By using both methods, it is expected to produce data of land use and settlement suitability in Bantul, especially the planning that considering the condition of the earthquake disaster that ever happened in 2006.

2. Remote sensing and GIS for mapping the land use

Remote sensing is needed to collect primary data from the surface of the earth [2]. Then, all of parameters that decided to use for analysis must to be overlaid one and another by Geographical Information System. Generally, Geographical Information System is a system design to manipulate, analyze, manage, and present all types of data, especially spatial data. Data resources that may be able to be processed by GIS are the data that came from surface of the earth, like the remote sensing data, and also the secondary data that collected from the research before, the existing maps or from government instances. Landsat Multispectral image has spatial resolution 30 meters, so it is suitable for the mapping in average area scope. Settlement classification mapping must have some requirements that contain topographic matters and policies.

3. Case study: Settlement suitability in Bantul

The research is located in Bantul District, which ever happened a strong earthquake. Particulary, the settlement located near the Opak Fault that had destroyed. The research made a landuse classification in the Bantul area at first, then we analized particularly in the settlement area in the next step.

3.1. Research location

Bantul District is located in the southern part of Daerah IstimewaYogyakarta Province. It is adjacent to Yogyakarta City and Sleman District in the north, Hindia Ocean in the south, Gunungkidul District in east and Kulonprogo District in the west. Bantul District lies between 07 ° 44 '04 "- 08 ° 00' 27" South latitude and 110 ° 12 '34 "- 110 ° 31' 08" East Longitude. The total area of Bantul is 508.85 km2 and consists of 17 sub-districts. Generally, the west part is is the less sloping areas and hills that stretches from north to south, covers about 89.86 km2 (17.73% of the total area). The middle part is flat and gently sloping area, is also an agricultural area that covers 210.94 km2 (41.62%). The eastern part is a sloping area but not too steep compared by the western part, covering an area of 206.05 km2 (40.65%). The south side which actually the central location of state has the beach and coastal area [6].

3.2. Data

The data needed to be proceed are Landsat Digital Image of Bantul, 2007, Topographic Map of Bantul, Earthquake Hazard Map of Bantul, Land use Map of Bantul, Soil Unit Map of Bantul, Map of slope classification, and data from previous research. Most of the data used for processing derived from primary data of previous studies. As the slope of the data derived from the Slope Classification Map, data of landform was interpreted using ASTER satellite image, data of land use and contour line was from Indonesian Topographic Map (Peta Rupa Bumi Indonesia) of Bantul sheet. The contour data can be classified using GIS to make the slope classification. In addition, disaster data such as the location and distribution of fault hazard zones derived from the geological map and previous research compiled by the

team PUSPIC UGM entitled *'Inventory and Mapping of Buildings Detail Tectonic Earthquake Damage after Using Remote Sensing Technology of IKONOS-PUSPIC due to Bantul earthquake disaster in 2006'*. Those maps then be overlaid and analyzed with the scored parameters using GIS. Then data of fault location as the main factor of the earthquake hazard also included to produce land use suitability, land use classification planning, settlement suitability, and settlement planning evaluation.

Fig 1. (a) LANDSAT satellite imagery of Bantul taped in 2002 , shown Stuctural Hiils of Batur Agung

4. Classification the suitability of land use (settelement) using GIS

The classification of land use, especially the settlement needs some parameters and factors to determine the suitability of each land use type [1]. We have considered the parameters according to previous research about settlement site selection.

4.1. Parameters, factors, and assumption of settlement compatibility

Parameters required in overlay data are slope, soil texture, distance from disaster zone, and landform [2]. All of parameters should be scored by score determination. And then all of parameters must be overlaid one and another to make an analitycal map.

4.1.1. Slope

The parameters used to clasify the settlement are considered by the condition of the physical land condition which are slope, landform, existing land use, soil type and also the factor of natural disasters. First, it is assumeded that the location of a settlement must be in the condition of the flat to gentle slope, because the construction of settlements on steep slopes would be more difficult and risky in security (not stable condition). In addition when viewed through a level of security against earthquake, the location of settlements located around the steep slopes are more dangerous.

4.1.2. Soil texture

The soil texture parameter used to determine the suitability of land settlement in Bantul is soil texture classification, assuming that the texture of the soil will greatly affect the establishment of the building especially when happened tremor. In addition, it is important to consider the landforms. Bantul is located

between structural landforms that are the source of the fault. The faults can contigently trigger earthquake.

Table 1. (a). Soil Texture Score ; (b) Slope Score

Soil Texture	Score
Loam	5
Sandy Loam	4
Clay Loam	3
Sandy Clay	2
Silty Clay	1

Slope Value (%)	Score
0 - 2	5
2 - 8	4
8 - 21	3
21 - <40	2
>40	1

Source : Sutikno (1991)

4.1.3. Landform & Disaster zone

Structural Mountains which is located in the eastern part of the district of Bantul, is Baturagung Hills. Therefore, it is very important that landform's parameter is used as source information of the location of the presence of the fault. The last parameter used to determining the direction of land use is the existing and recent land use (settlement) itself in Bantul. This is required to determine and evaluate the position of the existing settlement in Bantul considered by physical condition and the dangerous zone from the earthquake fault location.

Table 2. Landform Score

Landform	Score	Landform	Score
Alluvial Plains	5	Middle Slope	2
Foot Plain	4	Strong Eroded Denudasional Mountains	1
Lower Slope	3	Structural Hills	1
Karst Valley	3	Residual Hill	1
Karst	2	Marine	1

4.2. Wok Diagram

In summary we can present the steps of the research as following the diagram:

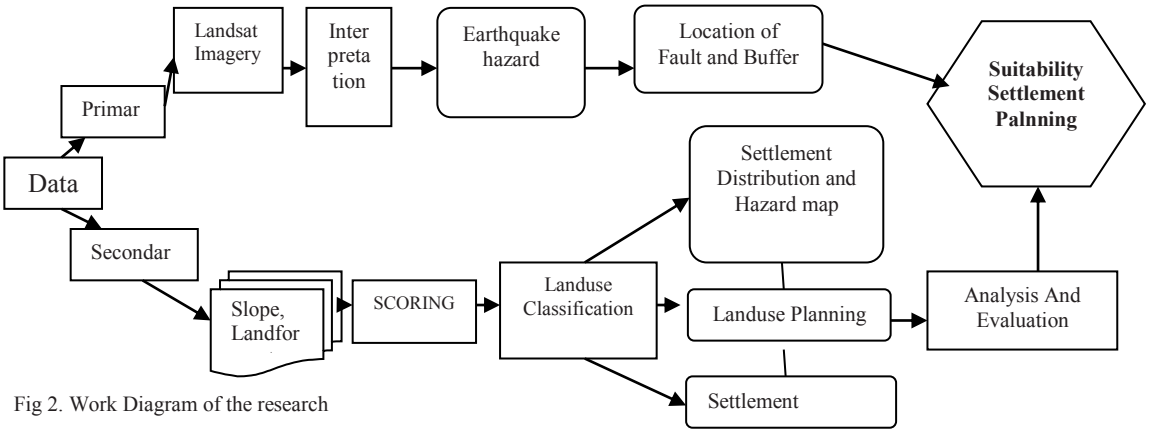

Fig 2. Work Diagram of the research

5. Creating land use planning map and settlement planning map based on earthquake hazard

Creating the map by overlaying all scored data using GIS. We have considered all paramaters and added the score for each paramater. The GIS system then will make re-classification according to the total score. For the land use planning map, we have only classified the land use in 3 groups, which are Region for Annuity Plant Cultivation, Buffer Zone, and Region for Seasonal Palnt Cultivation and Settlement. The scoring method resulted that the total score ranges from 5- 18. Then, we made 4 classes of the settlement suitability to simplify the condition, ranges from Not Suitable until Most Suitable.

5.1. Land use planning

The existance land use basically be made by adjusting the physical condition of earth surface. One of the land use that must be planned by the physical conditions is settlement. The selection of an appropriate and suitable location of proper settlement has a very important meaning in the spatial aspect, because it will determine the durability of the building, the economic and environmental impact on the surrounding neighborhoods (Sutikno, 1982). Land development planning and spatial arrangement for a settlement location based on the needs of the various fields with the basic requirements of physical considerations such as topography, natural resources, soil, geography, climate, and natural disasters (Prayogi, 1983 in Eko Budiharjo, 1984). The land evaluation should be done to determine the location of settlements, in order to make the conditions for settlement safe and health for the sustainability of the society.

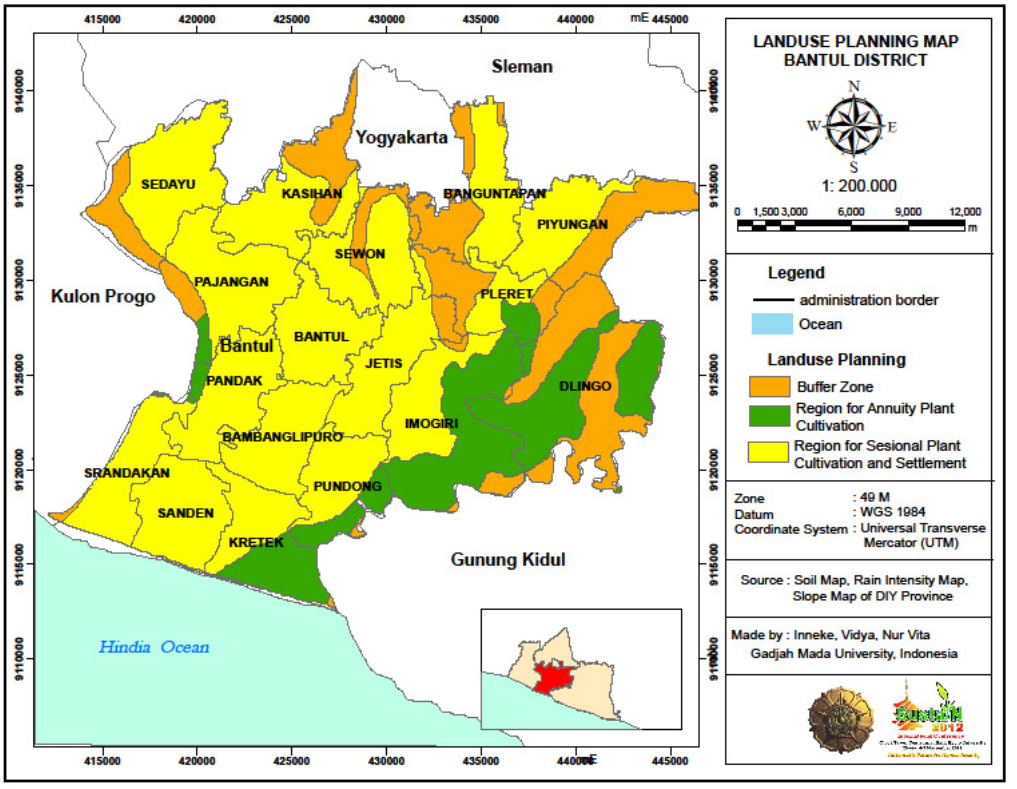

Fig 3. Landuse Planning Map in Bantul District

5.2. Settlement planning based on earthquake hazard

In general, the appropriate land use in Bantul District is 'seasonal plant cultivation and sttlement' such as rice, corn, etc. Thus, the recent settlements in Bantul generally right with the land use direction. However, it should be considered that a natural phenomenon which often occurs in Bantul is earthquakes because Bantul region itself is traversed by the primary fault lines were quite active. Then, the land use planning and direction must include earthquake hazard as a disaster mitigation activities. Based on the measurement and analysis, it shows that approximately 30% of the settlements in Bantul are in the danger zone (about 104 km2). The buffer of 'primary fault danger' ranges from 2-3 km away from the fault. So the unproper settlement needs to be re-located from that region.

Determination of the safe and feasible settlemet region made by the scoring method on physical spatial data such as slope, soil texture, land form, and other additional data which is common be used in land use direction or planning. Then, the spatial data are overlaid with one another to produce the appropriate information based on the physical ability of land settlement. In addition, as for the process of adaptation to the earthquake, it is conducted by overlaying spatial data of settlemet- land use direction with the earthquake (fault location) data.

The result of overlaid spatial data shows that almost 80% (about 416 km2) of the settlements in the district of Bantul has already in the most appropriate locations for settlement- land use. This happens because the Bantul district is located in alluvial landforms which is generally not only has pretty flat slope topography, but also has soil characteristics that are not too solid. This means that the existence of settlements in that region is quite appropriate because the land can support the use of settlements.

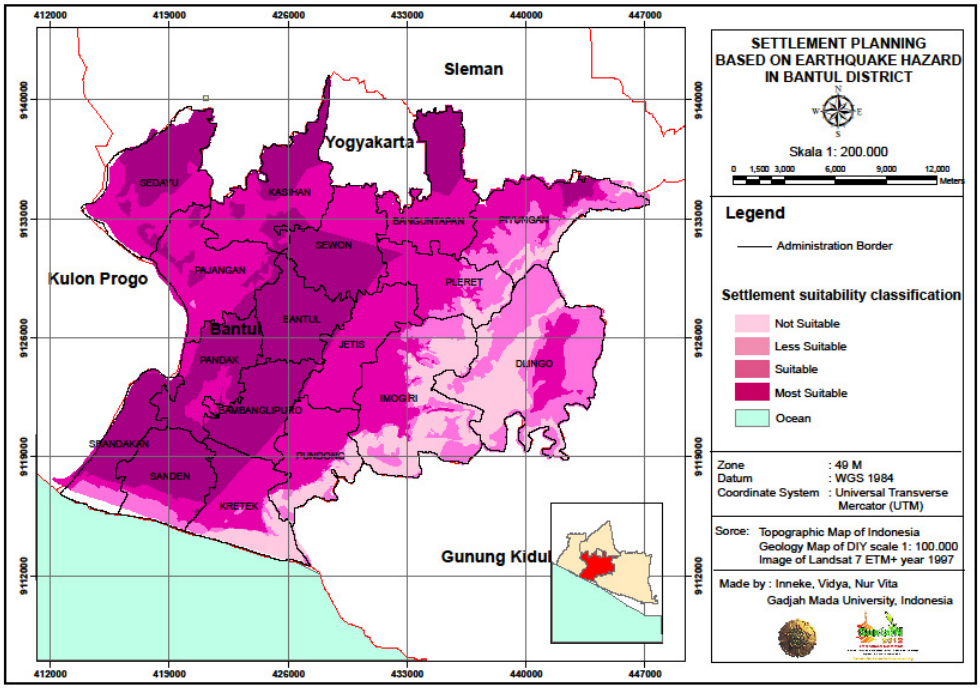

Fig 4. Settlement Planning Based on Earthquake Hazard in Bantul District Map

Data of land use direction which priorly have been made should be overlaid by seismic hazard data. Finally, it was found out that more than 30% (about 104 km2) of the settlements in Bantul are in earthquake-prone areas. It causes the suitability of land use decreased.

6. Settlement suitability analysis and planning evaluation

The evaluation is still needed to analyze the condition between the settlemet planning, the regional planning from goverment and the existing settlement in Bantul [5].

6.1. Settlement suitability map analysis according to earthquake hazard

As the results of Geographic Information System processes, we can conclude that the most suitable area for settlement has slope value between 2-8% (plain-moderate), it is located at a Alluvial Plain, with the soil type are Cambisol and Latosol. These soil types have kind of clay loam soil texture. Cambisol and Latosol soil type usually exist in Alluvial Landform and Stuctural Hill Landform. But, the most suitable area of settlement must be outside of earthquake hazard zone. These kind of soil type are more exact to support the building, especially for the settlement because they are more flexible and can be muffled the tremor. Sub-District of Sanden, Bambanglipuro, Pandak, Bantul, Srandakan, and Sewon are located outside of the earthquake hazard zone, and also located in Alluvial Landform, plain slope, and clay-loam soil texture. These are the sub-district of Bantul that have in the most suitable characteristic to built up settlement.

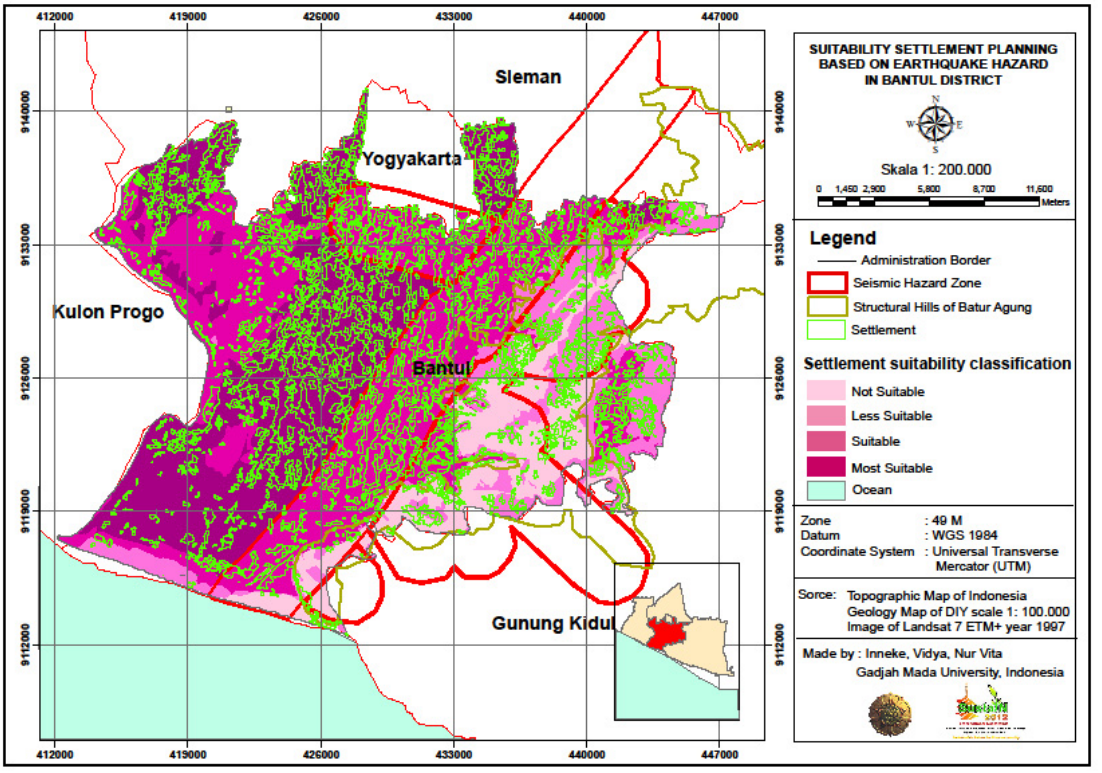

Fig 5. Suitability of Settlement Planning Based on Earthquake Hazard Map

Actually, Sub-District of Kretek, Pundong, Bangutapan, Pleret, Dlingo and Imogiri are also located in good physical condition of landscape, such as landform, slope, and also the soil texture, but these sub-district are located around of earthquake hazard zone due to the faults. Hence, all of the settlement that built up around that hazard zone are quite dangerous, as long as the earthquake disaster itself cannot be predicted.

We can see from the map (Fig.5) that the sub-district of Dlingo has the most inappropriate area for settlement to build up. Sub-district of Dlingo is located around of Structural Hill Landform. The Landform actually has good soil type for settlement, even for the slope itself could support the building of settlement because of the quite plain slope characteristic.

The 2006 earthquake disaster made the sub-district of Dlingo, Imogiri, and Pleret became one of the most damaged sub-district in Bantul (Inventory and Detail Mapping of Buildings Damage after Tectonic Earthquake Using Remote Sensing Technology of IKONOS-PUSPIC Geography Faculty of Gadjah Mada University) [3]. We can see from the map that those sub-districts located in the hazard zone, so it would be no wonder if it had the most damaged than the other sub-districts.

Earthquake hazard zone are made based on the distance from faults. The distance that being made is around 2-3 km in length, in order to make sure in around that distance is empty from any kind of settlement.

The existence of settlements in hazard areas will be very dangerous because basically the earthquake activities can not be predicted. Activities such as disaster mitigation are very important considering the many victims during the devastating earthquake moment in 2006. Mitigation activities can also be done by taking care with the characteristics of the different areas, especially the areas that have very high level exposure to the earthquake.

The settlement which is stil located in the danger zone was not really problematic, considering that the earthquake usually occurs unpredictable. However, some settlement areas near the fault should be more taken care before the earthquake occurs. Because it can very dangerous especially if the epicenterrum of the quake located on surface where many settlements flourish.

Table 3. Bantul Sub-District Building Damage caused by 2006 Earthquake

Sub-Ditsrict	Total Hard Building Damage
Dlingo	4435
Imogiri	9016
Pleret	9145
Sewon	15154
Pundong	5663
Pajangan	2337
Bangutapan	8563
Kasihan	5107

Source : Primary Data (IKONOS Imagery 28th May 2006 Taping)

6.2. Settlement planning evaluation by 'regional planning' from goverment

Through the map where the location of existing settlements (Fig. 6), it is showed that some areas of the site of the settlement was in the danger area. Hazard area is determined by the presence of the primary fault is in the hills along the eastern structural Baturagung, Bantul. The primary fracture extending from the south eastern part of the district of Bantul (D.I Yogyakarta Province) up to Central Java Province. Generally, the location of settlements in the district Bantul itself is appropriate, because it was in the

'seasonal plant cultivation and settlement' classification. The land use direction obtained through overlay data of slope, soil type, and rain intensity. Through those data, it can be determined the type of appropiate land use, because basically the classification and placement of a land use should be adjusted to the condition and the ability of the land itself, so it can support the existence of land use on it.

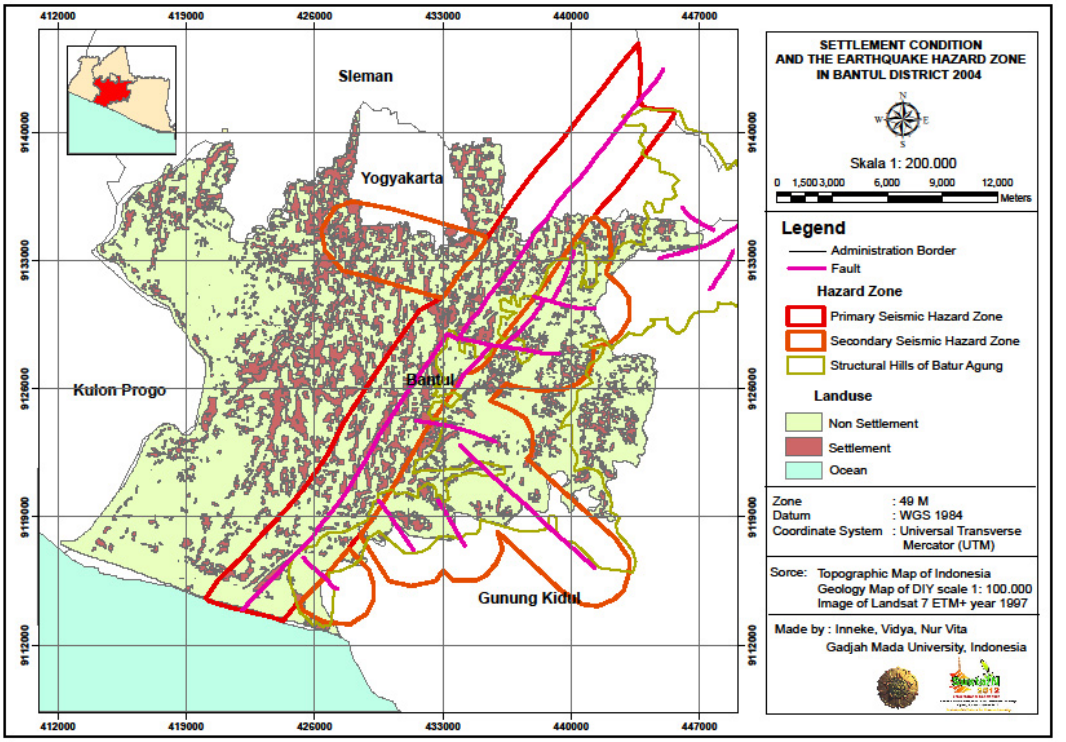

Fig 6. Settlement Distribution and Earthquake Hazard Zone Map

Generally, the direction of development and regional planning refers to 'Regional Planning' (RTRW Bantul) divided into 6 Unit Development Area [6] , namely:

- Unit I: District Sedayu. Directed to be wetland agriculture, industry and settlements.
- Unit II: Kasihan, Sewon, Banguntapan. Directed to be residential areas and urban-oriented services.
- Unit III: District Piyungan. Directed to be protected areas and agricultural wetlands subordinates.
- UnitIV: District Srandakan, Sanden. Directed to be wetland agriculture, housing and tourism.
- UnitV: Bantul, Pandak, Bambanglipuro, Kretek, Pundong Pleret. Directed to be industrial, residential, agricultural wetlands and nature.
- Unit VI: Imogiri, Dlingo. Directed to be agricultural cultivation, protected subordinates.

We can see on the map (Fig.6) that the hazard area of earthquake (near Opak Fault) is in the District Kretek, Pundong Bangutapan, Pleret, Dlingo and Imogiri. While the District Sanden, Bambanglipuro, Pandak, Bantul, Srandakan, and Sewon are including the safe and suitable area because it is far to the fault and have physical conditions that allow to be settlements. If we compare it with the regional planning made by Bantul government, it is already showed the appropriateness area when it is directed as a protected area (non-residential). For example in Imogiri, which the area is mostly near Opak fault, is

directed by the government as a protected area. This indicates that the government actually had already thought the hazard around the site.

7. Conclusion

Finally, It can be concluded that land use in any region of the earth's surface actually can be planned and directed by using a physical spatial information such as the existing slope conditions, and soil conditions. This method using remote sensing and GIS can also be carried out in areas that are highly vulnerable to earthquake hazards, such as in Bantul Distric, Yogyakarta.

The most suitable area for settlement have a plain slope (about 2-8%), it is located in Alluvial Landform, have clay-loam soil texture, located in Region for Sessional Plant Cultivation and Settlement, contain Cambisol or Latosol soil type, and located in outer of primary earthquake hazard zone. The unsuitable area for settlement has characteristic such as located in the earthquake hazard zone, steep slope, sandy texture and it is located in the structural hill, denudation hill, or in the volcanic area.

It also more safety because it has several distance (2-3 km) from the central of the fault (Opak fault) The result of overlaid data and final map shows that almost 80% (about 416 km^2) of the settlements in the district of Bantul has already in the most appropriate locations for settlement- land use. If, the buffer of 'primary fault danger' ranges from 2-3 km away from the fault, then it shows that approximately 30% of the settlements in Bantul are in the danger zone (about 104 km^2). The most suitable area for settlemet are in Sanden, Bambanglipuro, Pandak, Bantul, Srandakan, and Sewon district. On the other hand, some districts that have classification of inappropiate to be settlement based on the hazard of earthquake are Kretek, Pundong, Bangutapan, Pleret, Dlingo and Imogiri.

The 'Regional Planning' made by Bantul goverment actually has already considered the hazard of disaster, but unfortunately there is still some settlement built in the danger area. Strong structure of building also needed in order to make a strong settlement even in the hazard area.

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